V-14 Design, Construction and Quality Control Experience of Prefabricated Four (4) -Inch Reinforced Brick Panels

D.C. Cammer, C.E.T.
Chief of Building Code Activities, Brick Institute of America

D.C. Patterson, P.E.
Assistant Chief Engineer, Brick Institute of America

A.H. Yorkdale, P.E.
Director of Engineering and Research, Brick Institute of America

W.T. Ruth
Project Manager, Henry J. Knott, Inc.

J.H. Thomas
Assistant Director, Mid-Atlantic Region, Brick Institute of America

ABSTRACT

The utilization of prefabricated conventionally designed 4-in. reinforced brick panels is a growing, viable, economical method of construction in certain parts of the U.S. The paper will document this mode of construction used on three 5 story classroom buildings built in 1977 on the campus of the University of Maryland, Baltimore County, Maryland. Basic construction consisted of 4-inch reinforced brick panels constructed with cored brick units and portland cement, lime mortar and grout. Various aspects of the panel design will be examined, i.e., connection details, quality control, construction and erection. The panels were attached to steel frame structures.

All panels were built indoors under factory conditions, shipped to the job site and erected in cold weather. Consistent quality control testing was achieved throughout the construction process. To date, in-service performance has been satisfactory and the panels have not experienced leakage due to wind-driven rains. This problem is sometimes associated with single wythe brick panel projects.

Based upon the successful experience of this project, the paper will show that efficient, economical brick panels were produced using conventional portland cement, lime mortar and grout.

INTRODUCTION

This paper will discuss 4-inch thick reinforced brick masonry panel construction on a five (5)-story classroom building. Academic Building #4 was built for the University of Maryland in 1977. The brick panels are spandrel and column covers, attached to the structural steel frame and concrete floors. The panels are of similar design and construction as in the Administration Building for Coppins State College in Baltimore, Maryland. (See Ref. 1).

DESIGN

Panel design for spandrel beam and column covers generated into several forms, i.e., "C" and "L" shapes for spandrel beams, "V" shapes for column covers, and straight, flat sections for parapet elements and horizontal soffits. The primary panel shape discussed in this paper will be the "C"-shaped panel (see Fig. 1).

The panels were structurally designed to accommodate in-service, handling, transportation and erection stresses, resulting in a two-way reinforced 4-inch thick brick panel. Horizontal reinforcement bars, ½ or ⅝ inch in diameter, as required, were grouted into the cores of the hollow brick to resist flexural tensile stresses normal to the bed joints. The size and location of reinforcement bars vary to accommodate handling, service and erection load stresses for different size panels. Prefabricated welded wire joint reinforcement was placed in the mortar joints to accommodate flexural tensile stresses parallel to the bed joints.

Connections to the structural frame are steel clip angles bolted to the panels with ¾-inch diameter threaded bolts grouted into the cores of the brick. Weld plates were anchored to the concrete floor slab with shear bolts. Two clip angles, located approximately at mid-height of the panel, were selected in place of a continuous angle anchored the full width of the panel. The clip angles provided for two point loading and were less difficult to shim, as compared to shimming a continuous angle along the edge of the floor slab (see Fig. 2b). The top and bottom of the "C" panels were stabilized by steel clip angles welded to the steel frame (see Fig. 2(a) and (c)).

MATERIAL REQUIREMENTS

The extruded, side-cut, stiff-mud brick units, conform to ASTM C652, Standard Specification for Hollow Brick (Hollow Masonry Units Made from Clay or Shale), Grade SW, Type HBS. The required average minimum compressive strength on the gross unit area of five (5) units was 6,000 psi, with a minimum of 5,000 psi for any individual unit. The basic brick is a standard modular, 3-⅝ × 2-¼ × 7-⅝ inch unit. Basic units were manufactured

with a kerf, so that the end web could be removed or tapped out as required (see Figs. 3 and 4). A special shaped unit was designed and manufactured to accommodate 45° and 90° corners in the "C" panels.

MORTAR AND GROUT

Mortar consisted of a factory pre-bagged mixture of colored portland cement and hydrated lime. The mixture was proportioned to yield a Type S mortar after the addition of sand. The proportions by volume were one (1) part portland cement (ASTM C150, Standard Specification for Portland Cement), one-half (½) part hydrated lime (ASTM C207, Standard Specification for Hydrated Lime for Masonry Purposes), and four and one-half (4½) parts sand.

Grout for cells and cores consisted of mortar with the addition of more water to bring the cementitious mixture to a pourable consistency of a 10-inch slump.

To obtain the desired amount of fines and proper gradation in the sand, grading requirements, under ASTM C404, Standard Specification for Aggregates for Masonry Grout, were specified. Table 1 below shows the seven (7) sieve analysis fine aggregate of No. 2 size.

Reinforcement

Reinforcement bars, conform to ASTM A615, Standard Specification for Deformed Billet-Steel Bars for Concrete Reinforcement, Grade 40, new billet steel. Standard, prefabricated, ladder-type, joint reinforcement, for a single wythe, with No. 9 gage longitudinal side rods and cross ties, was used in the bed joints. All joint reinforcement was hot-dipped galvanized to guard against corrosion. Panel corners were horizontally reinforced with prefabricated corner pieces.

CONSTRUCTION

Factory Set-up

Panels were constructed indoors in a factory type of atmosphere. Conventional bricklaying methods were used to lay up units utilizing aluminum frames and string lines. Gas space heaters maintained an indoor temperature for the work crews of approximately 60°F in the winter time. The temperature and humdity were recorded continuously on a daily basis.

Fabrication

Brick were wetted when required prior to laying, with a lawn sprinkler. Mortar batching was controlled by accurate measurement of the ingredients. *Measurement by shovel was prohibited.* Ingredients were mixed in a mechanical batcher for a minimum of three (3) minutes and/or a maximum of five (5) minutes, with the maximum amount of water to produce a workable consistency.

There were approximately three hundred seventy (370) panels. The smallest was 1′ - 6″ × 3′ - 4″, and the largest, 10′ - 0″ × 14′ - 8″. Panels were specified and built within a ⅛-inch tolerance in 10 feet in either direction. Alignment of the panels under construction was controlled with a laser-beam level. Kerfed units were tapped out of the units by the bricklayers (see Fig. 4a). This was usually handled by one bricklayer working separately from the others. These units were then placed around the protruding reinforcement bar. After a full course was laid, all cells and cores were thoroughly grouted.

Panels were scheduled so that a whole panel could be completed on the same working day. A total of four hundred thousand (400,000) units were used to construct the panels.

After each panel was completed, it was allowed to cure before being cleaned and dampproofed on the unexposed side with a brushed-on, proprietary dampproofing cement slurry compound. Panels were stored and air-cured at 70°F where feasible. Generally, panels were not moved until curing had taken place for twenty-eight (28) days.

QUALITY CONTROL, TESTING AND INSPECTION

Pre-job testing was conducted on a series of prisms and mortar cubes for correlation with quality control testing during construction of the panels. Quality control testing and prism building was performed on a daily basis. Seven (7) and twenty-eight (28) day flexural strengths were obtained. The prisms were tested in accordance with ASTM C518, Standard Methods of Test for Flexural Bond Strength of Masonry. Five (5) stack bond, single wythe prisms were constructed each day in jigs, one (1) unit wide and seven (7) or ten (10) units high. Mortar cube testing was conducted on a daily basis (four (4) tests per day) in accordance with ASTM C109, Methods of Test for Compressive Strength of Hydraulic Cement Mortars. The average daily test results are shown in Table II. Sand also received a sieve analysis on a daily basis.

The brick panel engineer conducted daily inspection visits to the panel factory to assure that all construction progressed in accordance with the shop drawings and specifications. Panels were certified, upon erection at the job site, by the panel engineer that the design, materials, and workmanship, had been installed in accordance with the contract documents.

The masonry contractor required that all mortar joints, cells and cores be completely filled with mortar or grout. This type of workmanship was strictly enforced. Failure of the individual bricklayers to comply constituted grounds for immediate dismissal. The factory type of operation provided for year-round employment.

ERECTION

Panel erection procedures were similar to those executed at Coppins State College Administration Building. (See Ref. 1). Erection was accomplished in twenty-six (26) days during sustained cold weather at temperatures near and below 32°F. (December 1977 - January 1978). Travel distance from the plant to the job site was approximately three (3) miles.

PROJECT DESIGN AND CONSTRUCTION TEAM

Architect: Booth and Somers, Salisbury, Maryland
Structural Engineer: William Stevenson, P.E., Baltimore, Maryland
General Contractor: Lacchi Construction Company, Baltimore, Maryland
Masonry Contractor: Henry J. Knott, Incorporated, Baltimore, Maryland
Panel Engineer: George A. Evans, Jr., P.E., Inc., Baltimore, Maryland
Owner: State of Maryland, U.S.A.

REFERENCE

1. A Case Study - Four (4)-Inch Reinforced Brick Masonry Panels - Coppins State College Administration Building, Baltimore, Maryland, U.S.A., D. Cammer, D. Patterson, A. Yorkdale, W. Ruth, and J. Thomas, 1979.

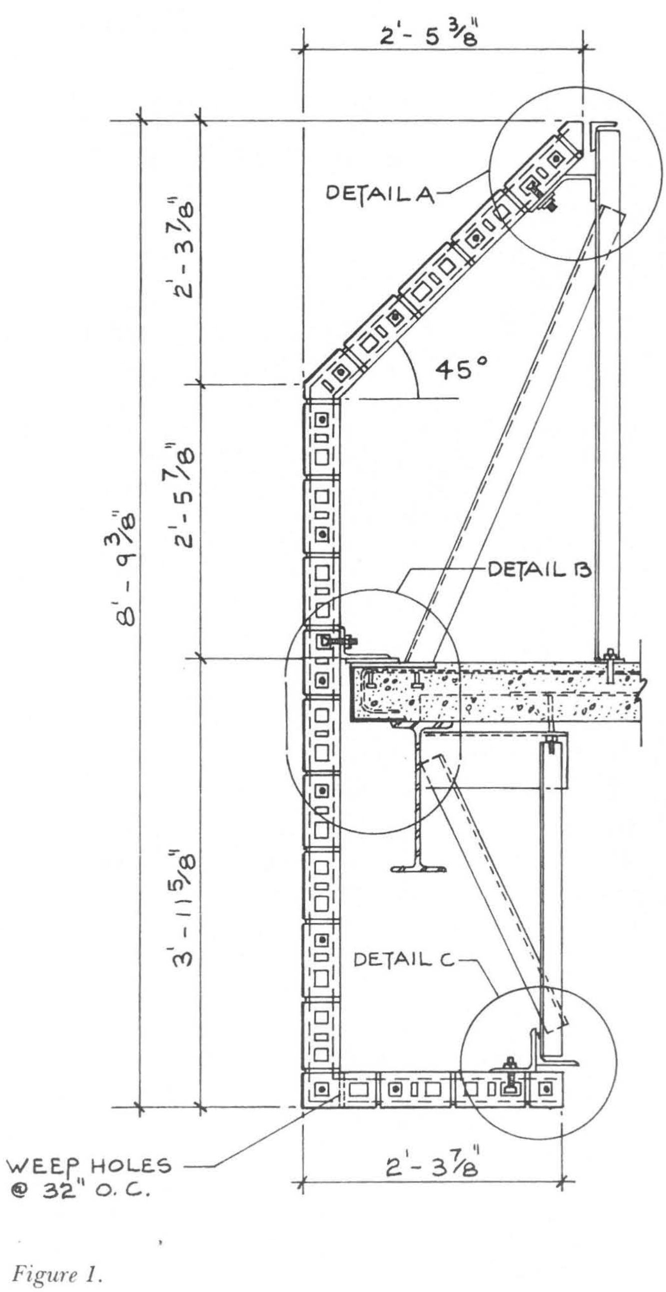

Figure 1.

TABLE 1

Sieve Size	Percent Passing
No. 4 (4.76 mm)	100
No. 8 (2.38 mm)	95–100
No. 16 (1.19 mm)	60–100
No. 30 (595 Micron)	35–70
No. 50 (297 Micron)	15–35
No. 100 (149 Micron)	2–15
No. 200 (74 Micron)	———

TABLE II—Average Daily Test Results

Mortar Cubes		Flexural Prisms	
7 days	28 days	7 days	28 days
1300 psi	1800 psi	161 psi	198 psi

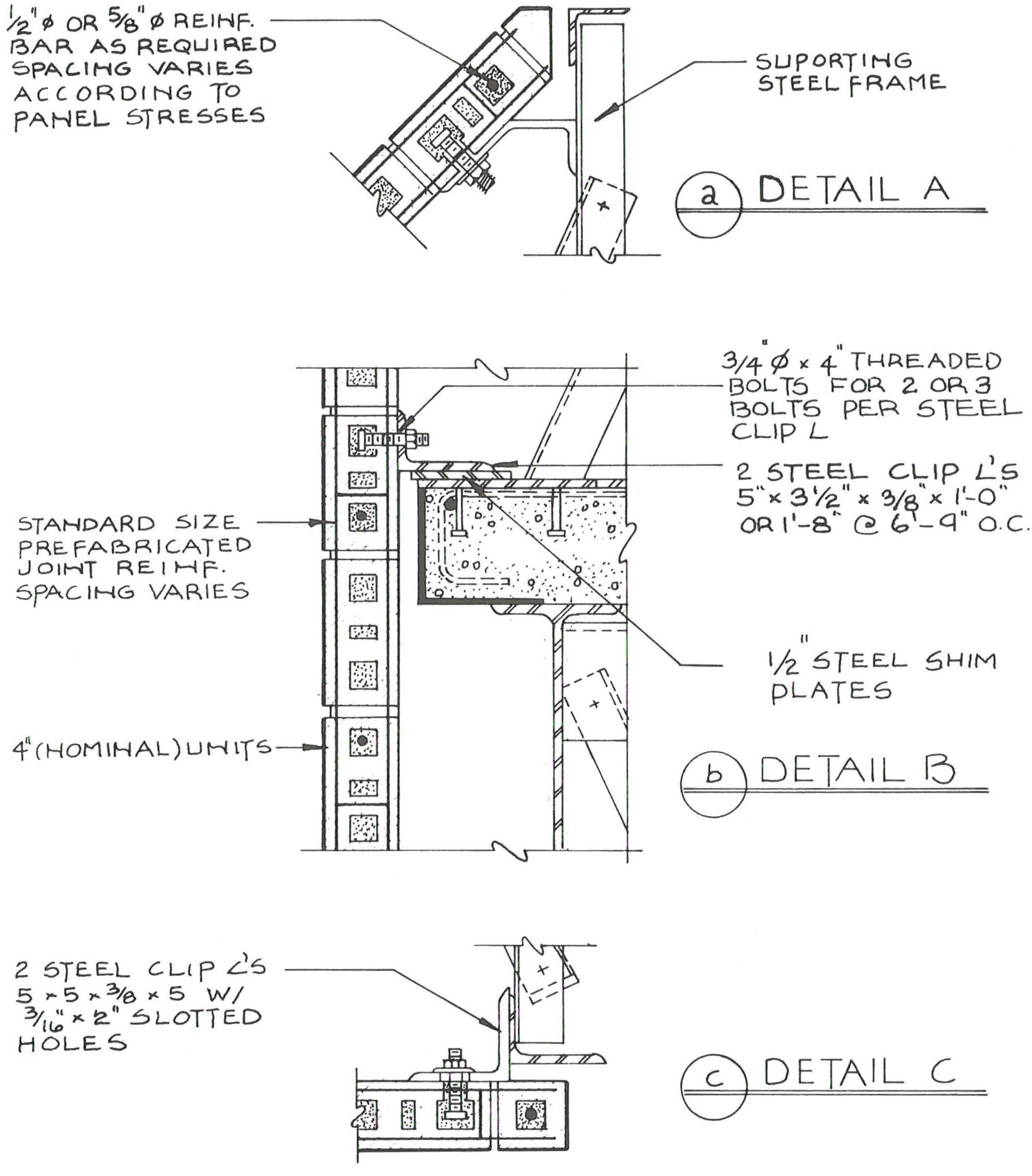
1/2" ø OR 5/8" ø REINF. BAR AS REQUIRED SPACING VARIES ACCORDING TO PANEL STRESSES
SUPORTING STEEL FRAME
a DETAIL A
3/4" ø x 4" THREADED BOLTS FOR 2 OR 3 BOLTS PER STEEL CLIP L
2 STEEL CLIP L'S 5" x 3 1/2" x 3/8" x 1'-0" OR 1'-8" @ 6'-9" O.C.
STANDARD SIZE PREFABRICATED JOINT REINF. SPACING VARIES
1/2" STEEL SHIM PLATES
4" (NOMINAL) UNITS
b DETAIL B
2 STEEL CLIP L'S 5 x 5 x 3/8 x 5 W/ 3/16" x 2" SLOTTED HOLES
c DETAIL C

Figure 2.

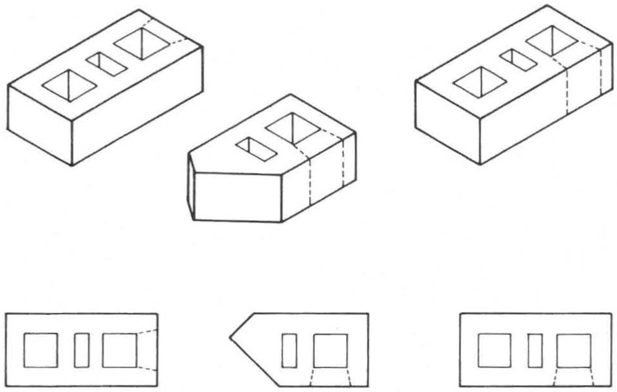

Figure 3.

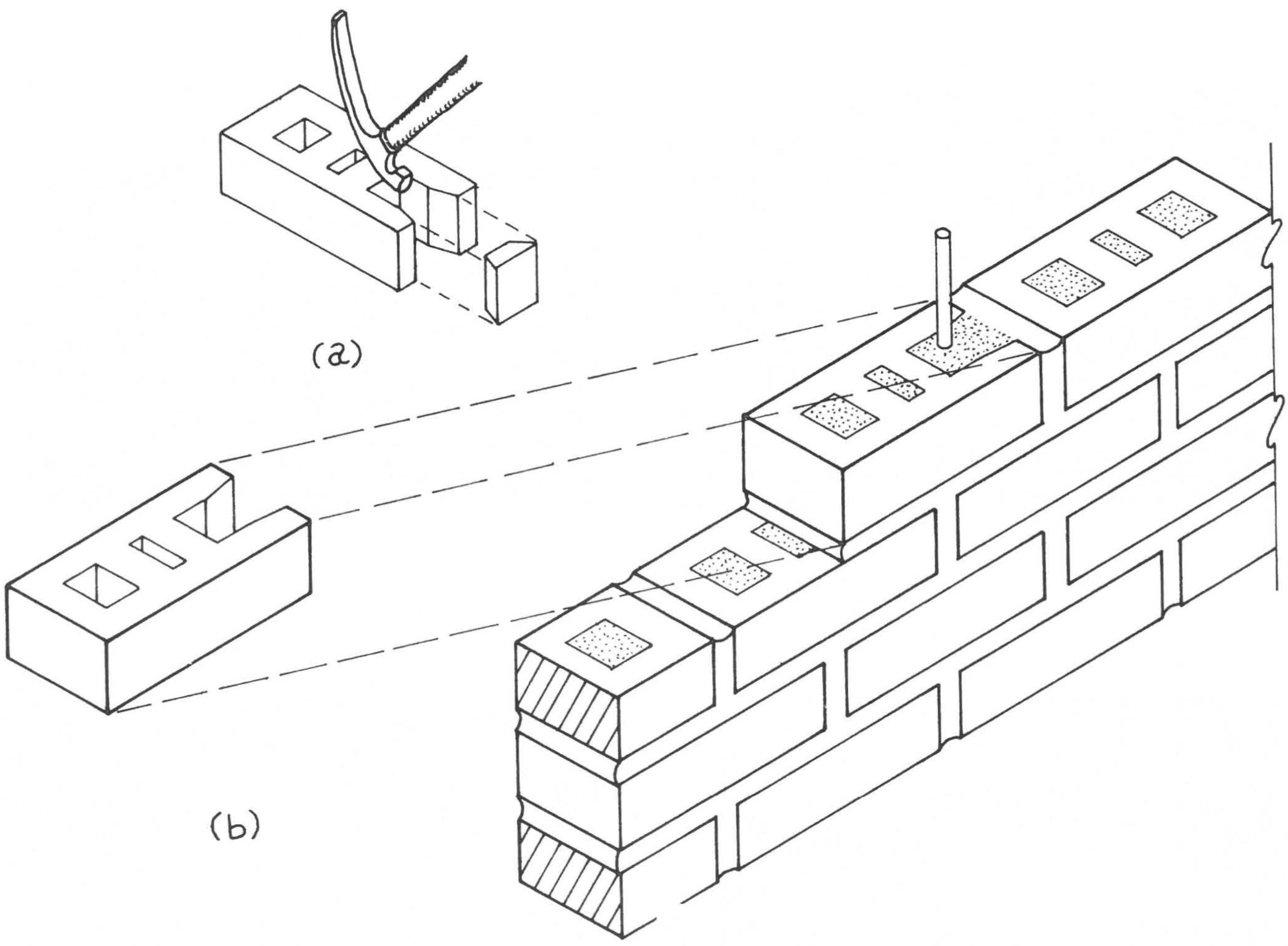

Figure 4.

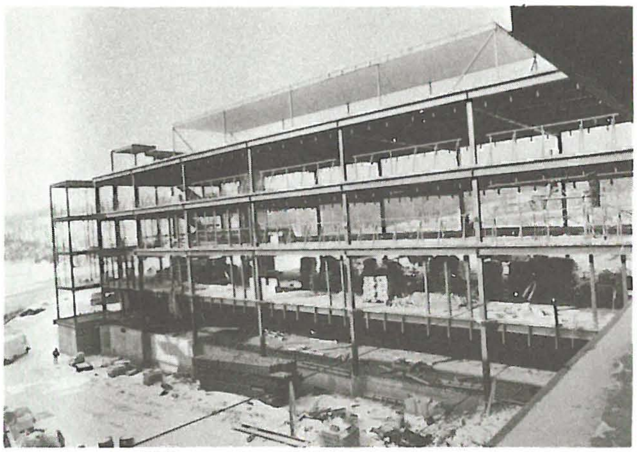

Figure 5. Building Frame Before Erection of Panels

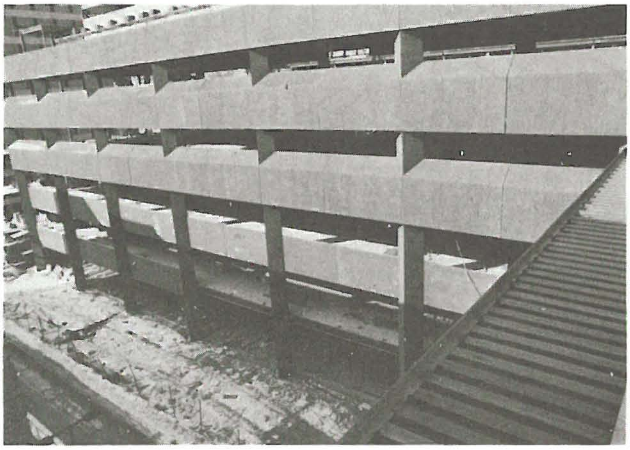

Figure 6. Building After Erection of Panels

Figure 7. Erection of "C" Shape Panel

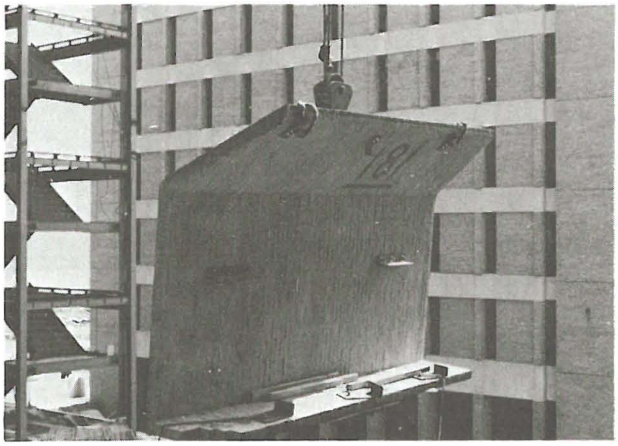

Figure 8. "C" Shape Panel

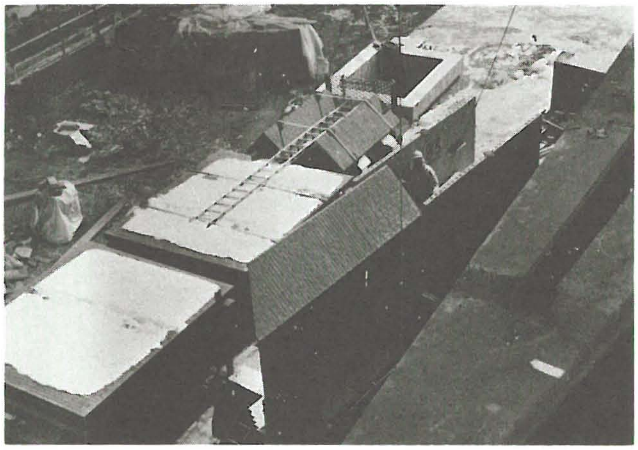

Figure 9. Panels on Truck Ready for Erection

Figure 10. Panels Stored at Prefabrication Plant, Ready for Shipment